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Period and Light Curve of 6685 *Y Lyræ.**

By A. Stanley Williams.

The earlier observations of this star seemed to suggest a moderately long period, and one of about eighty-six days was proposed by Dr. Hartwig in 1900,† whilst at about the same time I thought it might be forty-two days, or about half the above value. Observations of the star were commenced here in 1901 May with the object of solving this question, and after these had proceeded for some time it became evident that the real period was actually a very short one. The question was finally decided on August 18, on which date the star was observed shortly before the rise from minimum had commenced, and followed up to and past maximum; whilst further observations soon showed that the true period was very nearly half a day. About the same time Dr. Hartwig was making a series of observations of the star at the Bamberg Observatory. His earlier observations are referred to in *A.N.* 3744.‡ These were inconclusive, but further observations in the latter part of August made him suspect that the variable had a short period. Dr. Hartwig was unable to continue his observations at this time, but later on he was able to fully confirm the rapid variability of the star, and his observations are in good agreement with the others.

The results contained in the present paper are based upon a total of 239 visual observations. Fourteen of these were made by Dr. Hartwig with the 10-inch Bamberg refractor. The others were made at Hove with a 6½-inch reflector, a power of 110 being usually employed, but occasionally one of 225 was made use of on moonlight or hazy nights. These observations are all included in the period comprised between 1901 May 13 and November 3. The following is a short description of the method of observation, the reduction of the observations, and the determination of the magnitudes of the comparison stars.

In order to eliminate the effects of what has been called "position error," three principal methods may be employed, namely (1) we may observe the group of stars under all possible angles of position with respect to a line through the eyes; (2) we may observe the group with the eyes always in the same position; and (3) in comparing each comparison star separately

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* The star is designated *X Lyræ* in the "Companion to the Observatory." Its place for 1900 is α 18^{h} 34^{m} 12^{s}, $\delta + 43° 51'\cdot 8$.

† *Vierteljahrsschrift d. Astr. Gesell.*, Jahrg. 35, Heft 4, p. 276.

‡ In this note doubt is thrown upon the identity of the variable with a star of about 12^{m}, but they are actually one and the same object. It will appear from the present investigation that the light curve is rather a peculiar one, and that the star is only at all bright for about three hours out of twelve, whilst the period is so nearly half a day that it is possible to observe the star night after night for a long interval of time without any decided change of brightness becoming apparent.

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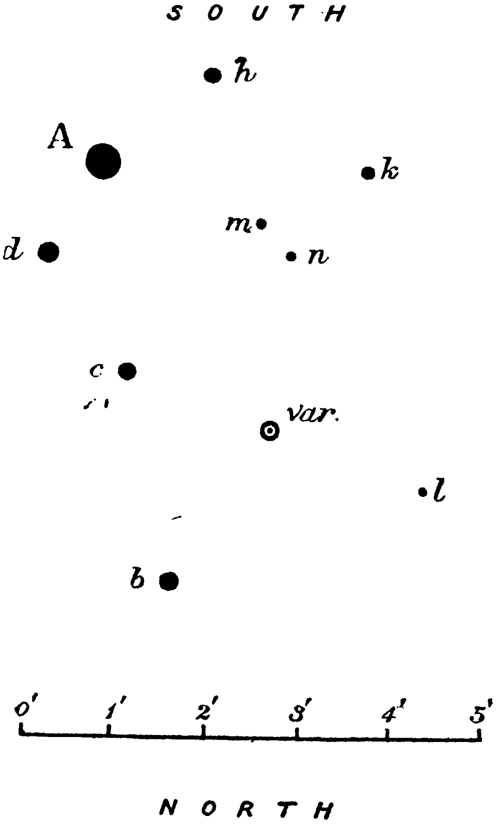
with the variable we may always observe with the eyes parallel to, or in some fixed position with respect to, a line joining the two stars observed. The first of these methods will undoubtedly give the best results, since with it the effects of position error must be altogether eliminated. Its only drawback is that the time and labour required are both much increased—a serious matter, especially in the case of a faint and rapidly varying star.* Method (2) was made use of in the present series of observations.† The group was always observed so that a line through the stars A and *b* (see diagram below) was normal to a line through the eyes, *b* being above. By this method the effects due to position error are not eliminated, so far as regards the absolute magnitude of the star observed, but the observations will be strictly comparable *inter se*.‡



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* In connection with this method and the question of position error generally reference should be made to the valuable papers by Dr. A. W. Roberts in the *Monthly Notices*, vol. lvii. p. 483, and vol. lix. p. 524.

† These remarks relate only to the Hove observations except where otherwise mentioned. Method (3) seems preferable on the whole to method (2), and is the one at present made use of by the writer. The reflector with rotating tube is very convenient for either method.

‡ The effect of a complete reversal of position is to produce a change of about half a magnitude in the relative brightness of two stars observed in a direction normal to a line through the eyes by the writer.

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The comparison stars used are shown in the preceding diagram.* The observations were made by the method of Argelander, and the step values of the different comparison stars, as derived from the very numerous comparisons between the latter and the variable, are as under :—

Comp. Star.	Step Value.	Adopted Mag.
c	0·0	10·70
h	5·5	11·09
k	13·0	11·63
m	14·8	11·75
n	18·1	11·99
l	19·7	12·10

The magnitude of the star *c* was assumed to be 10·7, chiefly from its visibility in a 2¾-inch refractor. On a clear night it is just distinctly and *steadily* visible, with a power of 75 on this instrument. The 6½-inch reflector has been considered to show distinctly and steadily stars down to $12^{\mathrm{m}}{\cdot}5$ on clear nights with a power of 110. The comparison star *l* is near, though decidedly above, this limit, and its magnitude has been assumed to be 12·1. Assuming the foregoing values for *c* and *l*, the magnitudes of the other comparison stars, as determined from the step values, are given in the last column of the above table, the value of a step being $0^{\mathrm{m}}{\cdot}071$. With reference to the comparison stars, it may be mentioned that *c*, *h*, and *l* have always appeared steady in brightness, and the comparisons made with them were usually satisfactory and consistent, particularly those with *l*. The other three stars *k*, *m*, and *n* have proved more unsteady, so that the comparisons with them were seldom quite satisfactory : *k* in particular has fluctuated so much as to give rise to the suspicion that it may be variable.

A somewhat elaborate system of weighting has been used in reducing the observations. The method of Argelander is capable of yielding most accurate results so long as the difference in brightness of the two stars compared does not exceed a few steps ; but in proportion as such difference exceeds, say, 3 or 4 steps the result becomes less and less reliable. The following weights were finally adopted :—

	Weight
Comparisons with *l* not exceeding 3 steps	3
Comparisons with *l* above 3, but not exceeding 7 steps	2
Comparisons with other stars not exceeding 3 steps ...	2
Comparisons with *l* exceeding 7 steps	1
Comparisons with other stars exceeding 3 steps ...	1

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* The positions of *h*, *k*, *m*, and *n* are only roughly estimated, but will be near enough to identify the stars. The bright star A is B.D. + 43°·3029 (8·1 mag.).

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The comparisons with *l* were given increased weight because this star proved more satisfactory than any of the others. All the observations were reduced with the above weights, excepting that in a few cases less weights were assigned when the notes made at the time of observation seemed to show that this was necessary.

From a preliminary determination from 5 maxima observed between 1901 August 19 and October 20 the period of variation was found to be approximately $12^{h}\ 3^{m}\ 40^{s}{\cdot}6$. For the final determination of this element, however, photographic observations have been used, chiefly on account of the much greater length of time available. Two photographs, dated 1899 December 31 and 1900 September 3, show the variable exactly of the same relative brightness with respect to *c*, in both the two stars appearing as a double star with slightly unequal components.* These photographs were taken with a 4·4-inch portrait lens of about 20 inches equivalent focus, and a third one obtained with the same instrument on 1901 November 5 also shows the variable of the same brightness with respect to *c*. In the case of photographs of a rapidly varying star there is necessarily some uncertainty as regards the exact time corresponding to the image of the star on the plate. As the exposures are not very dissimilar,† it has been assumed in the present instance that this time corresponds to the middle of the exposures. As we are now only concerned with the period of variation, and not with the time of maximum, it is immaterial whether this assumption is correct or not, provided that this time corresponds to the same phase in all the photographs. Below are given the date and heliocentric Greenwich mean time of the exposures and the duration of the latter. The fifth column contains the interval in time by which the observations follow the adopted epoch of T_0 ‡, and the last column the difference from the mean.

Plate.	Date.	Time.	Exposure.	Interval from T_0.	Diff. from Mean.
		h m	m	h m	m
46	1899 Dec. 31	6 40·4	63	0 54·2	−0·6
63	1900 Sept. 3	14 19·3	45	0 56·7	+1·9
149	1901 Nov. 5	9 9·4	32	0 53·6	−1·2

From these three observations the period of variation is :—

$$0^{d}{\cdot}5026876 = 12^{h}\ 3^{m}\ 52^{s}{\cdot}21$$

The remarkably close accordance of the three observations is no

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* The photographic brightness of the variable is the same as the visual.

† Plate 46 was exposed longer than the others, but the night was slightly hazy, particularly towards the end, and this would tend to equalise matters.

‡ The time T_0, as explained further on, is the time when the variable attains to equality with the comparison star *l* in its rapid rise from minimum to maximum.

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doubt to some extent an accident, but the star varies so rapidly near the time of maximum that I cannot think that any one of them can be in error by as much as 10^{m}, and the above period cannot be far wrong owing to the considerable interval of time covered by the observations, 1,341 periods being included between the first and last. It also satisfies all the visual observations.

Since the rise from minimum to maximum occurs with great rapidity, the instant when the variable attains to equality with the comparison star *l* has been adopted as the principal epoch. This instant is designated by T_0. There are twelve nights on which the variable was observed from minimum to maximum, and on eleven of these the maxima were also completely observed. The observations of each of these twelve nights were plotted separately upon squared paper, and a light curve drawn. From these light curves the times of T_0, and also the times of maximum, were determined by measurement. No mean light curve was made use of in this part of the work, but the results for each night were derived separately from the observations of that night. The reason for this was, chiefly, that some of the maxima seem to have been less acute than others, and I am not satisfied that this is all due to errors of observation. But though the maxima differ slightly in this way, the rise from minimum to near maximum is in every case represented by a straight line, so that the time T_0 can be very exactly determined. Table I., below, contains the dates and heliocentric Greenwich mean times of T_0. The mean of these times, corresponding to 1901 September 4, 12^{h} 20^{m}, has been adopted as the principal epoch.

TABLE I.

Observed Times of T_0.

No.	Date.	Observed Time.	Computed Time.	O–C.
	1901.	h m	h m	m
1	Aug. 18	10 24·4	10 8·7	+15·7
2	19	10 12·3	10 16·5	− 4·2
3	20	10 12·3	10 24·2	−11·9
4	21	10 32·3	10 31·9	+ 0·4
5	22	10 42·2	10 39·7	+ 2·5
6	23	10 43·2	10 47·4	− 4·2
7	24	10 52·2	10 55·2	− 3·0
8	26	11 13·1	11 10·6	+ 2·5
9	Sept. 4	12 5·3	12 20·3	−15·0
10	Oct. 20	6 10·3	6 12·5	− 2·2
11	25	7 1·0	6 51·2	+ 9·8
12	Nov. 3	8 10·5	8 0·9	+ 9·6

The greater accordance of observations 4, 5, 6, 7, and 8 is probably due to the observer having acquired a settled manner

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of observing and to the favourable weather prevailing at that time. No. 11 is from observations by Dr. Hartwig, and the residual here includes any error in the reduction of his observations to the scale of the others. With regard to this point there is a little uncertainty, since the Bamberg observations, made with a refractor, seem to make the star a little brighter than those made with the reflector.*

Table II., below, contains the observed times of maximum, with the intervals by which these follow the observed times of T_0.

TABLE II.

Observed Maxima.†

Date.	Greenwich M.T. h m	Interval from T_0. h m
1901 Aug. 18	11 51	1 29
19	11 32	1 22
20	11 34	1 24
21	11 33	1 3
22	11 33	0 53
23	11 45	1 4
24	12 13	1 23
26	12 11	1 0
Sept. 4	13 32	1 25
Oct. 20	7 10	0 59
Nov. 3	9 12	1 0

The mean of the times in the last column is 71^m, but from the mean light curve the interval is 60^m. The latter has been adopted as the true interval. The separate results vary from 53^m to 89^m, a difference which seems too great to be ascribed wholly to errors of observation.

The reduced observations of magnitude, having been arranged in order of distance from the time T_0, were formed into groups.

* Dr. Hartwig's observations are given below. The last column contains the magnitude according to the adopted scale.

	Greenwich M.T. h m	m		Mag.
1901 Oct. 25	7 1	*c* 0·74 Y		12·08
	7 12	*c* 0·7 Y		12·03
	7 23	*c* 0·4 Y	0^m·35 *l*	11·46
	7 33	*c* 0·25 Y	0^m·5 *l*	11·17
	7 41	*c* 0·15 Y		10·98
	7 57	*c* 0·15 Y	0^m·6 *l*	10·98

The night was not favourable, and cloud stopped observation after 7^h 57^m. The rapid rise from near minimum to maximum is, however, very well shown, and, as in my observations, is represented by a straight line.

† Not reduced to the Sun.

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For one hour before and two hours after T_0 the observations have been collected into 10-minute groups. The interval of 14^m preceding this epoch was divided into two equal groups. For the remaining portion of the period the observations have been formed into half-hourly groups, excepting between 5^h and 10^h after T_0, where they are not numerous enough to permit of this. Table III. contains the results of this grouping.

Table III.

Grouped Observations.

No.	Interval from T_0.	Observed Magnitude.	Magnitude from Curve.	O−C.	Weight.	No. of Obs.
	h m			m		
1	0 4	12·01	12·01	0·00	37	12
2	0 13	11·85	11·85	·00	48	10
3	0 25	11·65	11·65	·00	54	13
4	0 35	11·49	11·48	+ ·01	37	11
5	0 45	11·35	11·35	·00	43	11
6	0 53	1·33	11·33	·00	38	9
7	1 5	11·35	11·33	+ ·02	38	9
8	1 17	11·35	11·36	− ·01	14	4
9	1 24	11·39	11·39	·00	32	8
10	1 34	11·49	11·44	+ ·05	19	4
11	1 44	11·44	11·48	− ·04	33	9
12	1 56	11·54	11·54	·00	17	5
13	2 14	11·62	11·63	− ·01	60	15
14	2 43	11·78	11·77	+ ·01	55	12
15	3 15	11·90	11·90	·00	59	13
16	3 42	11·96	11·97	− ·01	30	8
17	4 16	12·04	12·04	·00	49	10
18	4 42	12·08	12·09	− ·01	11	3
19	6 54	12·26	12·26	·00	6	2
20	8 18	12·31	12·32	− ·01	27	9
21	9 27	12·30	12·34	− ·04	15	5
22	10 13	12·40	12·35	+ ·05	16	7
23	10 47	12·37	12·35	+ ·02	18	8
24	11 4	12·36	12·34	+ ·02	16	7
25	11 16	12·33	12·33	·00	16	5
26	11 25	12·28	12·33	− ·05	14	5
27	11 36	12·35	12·32	+ ·03	13	6
28	11 47	12·27	12·27	·00	21	7
29	11 53	12·22	12·22	·00	17	6
30	11 59	12·19	12·17	+ ·02	18	6

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In the above table col. 1 contains the number of the group; col. 2, the interval from T_0; col. 3, the observed magnitude, this being the weighted mean of the observations forming the group; col. 4, the mean magnitude, measured from the mean light curve; col. 5, the residual, observed − curve; col. 6, the weight, this being merely the sum of the weights of the separate observations; and col. 7, the number of observations to the group.* The 30 observed magnitudes having been plotted upon a large scale diagram, the mean light curve was carefully drawn, and the magnitudes in the 4th col. were measured from this. This light curve, on a smaller scale, is reproduced in Plate 7. The observations are in very satisfactory accordance, the average deviation of a group from the mean light curve being only 0·014 mag., whilst no residual exceeds 0·05 mag. It should be mentioned, moreover, that the observations forming a group are also generally very accordant, and that no observation has been rejected for discordance. The only observations not used consist of a few in which the variable was not seen, and was accordingly noted only as being fainter than a certain magnitude.

It will be seen that the mean light curve presents some rather peculiar features. The rise from minimum to maximum is very rapid; whilst immediately after the latter is attained the decline sets in, and the fall, though not so rapid as the rise, is yet very quick for the first two hours after maximum. One result of this is that the variable is only at all bright for about three hours out of the twelve, and for the remaining nine hours it is more or less faint. The light curve has thus a very close resemblance to that of what has been termed the "cluster type" of variable. This type has been recently described very fully in an interesting article by Professor S. I. Bailey,† in which the approximate light curves from photographic observations of eight of the variables in the cluster Messier 5 are reproduced. Reference should also be made here to a paper by Professor E. E. Barnard ‡ on visual observations of some of the variables in the same cluster, and to one by Professor E. C. Pickering § on the rate of increase of the light of three variable stars in the cluster Messier 3. In length of period also the present variable star bears a close resemblance to those of the cluster type, the average period of forty variables in Messier 5 being $12^h\ 37^m{\cdot}4$ according to Bailey, whilst the periods of the three in Messier 3 investigated by Pickering are stated to be $12^h\ 12^m\ 25^s$, $12^h\ 0^m\ 15^s$, and $12^h\ 24^m\ 31^s$.

Although the presence of so many variables of the type in star clusters would seem to show that such a condition is

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* Each of these separate observations is itself generally based on comparisons with from two to four comparison stars.

† *Astrophysical Journal*, vol. x. pp. 255–260.

‡ *A.N.* 3519.

§ *Astrophysical Journal*, vol. xii. p. 159. See also a valuable paper by the same writer on variable stars in clusters in *A.N.* 3525.

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peculiarly liable to give rise to this kind of variation, yet the existence of isolated stars, like *Y Lyræ*, belonging to the same class would indicate that it is not an essential condition. In other words the type is not peculiar to clusters.

Elements of Y Lyræ.

Period of variation	$0^{d}{\cdot}5026876 = 12^{h}\,3^{m}\,52^{s}{\cdot}21$.
Epoch of T_0	1901 Sept. 4, $12^{h}\,20^{m}$ G.M.T. (J.D. 2415632·5138.)
Epoch of maximum	1901 Sept. 4, $13^{h}\,20^{m}$ G.M.T. (J.D. 2415632·5554.)
Maximum brightness ...	$11^{m}{\cdot}32$.
Minimum „ ...	$12^{m}{\cdot}35$.*
Minimum to maximum ...	$1^{h}\,40^{m}$.†
Maximum to minimum ...	$10^{h}\,24^{m}$.
Ratio increase to decrease ...	0·16.

Computed Times of T_0.‡

1902.	G.M.T. h	m	1902.	G.M.T. h	m
April 1	3	6	Aug. 9	19	52
11	4	23	19	21	10
21	5	41	29	22	27
May 1	6	58	Sept. 8	23	44
11	8	16	18	0	54
21	9	33	28	2	11
31	10	50	Oct. 8	3	29
June 10	12	8	18	4	46
20	13	25	28	6	4
30	14	43	Nov. 7	7	21
July 10	16	0	17	8	38
20	17	17	27	9	56
30	18	35			

Hove: 1902 *January* 4.

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* According to Dr. Hartwig, the actual range of variation is somewhat less than a magnitude.

† It has been assumed that the minimum occurs just before the rise commences, but the star actually remains practically stationary for two or three hours before the commencement of the rise.

‡ The maxima will follow these times by one hour.

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Σ 1639. 68 *Comæ Berenicis.* By Thomas Lewis.

R.A. $12^h\ 19^m\ 25^s$ } 1900 Mag. A 6·7
N.P.D. 63° 52′ } 1900 Mag. B 7·9

The measures commence in 1827 by W. Struve; but they are few in number owing to the closeness of the components since 1880. It is undoubtedly binary, and as the distance is now increasing again it will become a fairly easy object and is worth attention.

Of course the orbit here given is only approximate, and is intended merely to call attention to the pair.

The annual means of the measures are :—

Year.	Angle.	Distance.	
	°	″	
1827·28	291·2	1·27	Σ (1)
29·39	289·7	1·15	Σ (3)
36·49	292·8	1·18	Σ
41·39	289·7	1·03	OΣ (1)
42·37	285·5	1·19	OΣ (2)
43·33	293·7	0·98	Maed. (1)
44·32	289·2	1·18	OΣ (1) Maed. (1)
48·35	288·8	0·96	Maed. (1)
55·32	282·2	0·97	OΣ (1)
56·48	288·1	0·87	Secchi (1)
57·33	283·6	0·84	Secchi (1)
58·34	283·0	1·00	De (4)
63·16	285·7	0·67	De (4)
70·31	275·8	0·74	OΣ (1)
75·25	273·6	0·40	De (1) Schiap. (4)
76·46	272·6	0·39	De (1)
77·41	271·4	0·40	De (1) Schiap. (4)
78·31	268·3	0·36	De (1)
79·31	268·7	0·4	Schiap. (2)
81·37	260·7	0·4	Schiap. (2)
82·39	258·1	0·39	Schiap. (4)
83·30	259·5	0·34	Engel (16) Schiap. (3)
84·37	243·7	0·38	Schiap. (2)
85·41	249·0 (?)	...	Schiap. (2)
87·39	236·0	0·22	Schiap.
89·40	215·6	0·2	H. Struve (1)
90·46	Single		H. Struve